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A Preliminary Assessment of the Groundwater Potential of Ekiti State, Southwestern Nigeria, using Terrain and Satellite Imagery Analyses.

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Abstract
A preliminary investigation involving the interpretation and analyses of hydrogeomorphological and remote sensing data had been carried out in the Basement Complex terrain of Ekiti State, Southwestern Nigeria. This was with a view to assessing the groundwater potential of the state. The Topographic map and Landsat Mapper (TM) satellite imagery (1986) of the study area were acquired and processed using the ArcGIS and ERDAS Imagine Software. The hydrogeomorphological, lineament density and lineament intersection density maps were generated from the processed remote sensing data. Hydrogeomorphological, lineament density and lineament intersection density maps were integrated for the classification of the study area into different groundwater potential zones. Five hydrogeomorphological units including hills/ridges, pediments, pediplains, pediplain with alluvium, and valleys were delineated in the study area. The lineament map showed that the linear structures in the study area generally trend along N-S, ENE-WSW, E-W and NW-SE directions. The lineament intersection nodes dominated the northwestern, western and south-eastern parts of the study area. Both the hydro-significant lineament and lineament intersection density maps revealed five (5) lineament cluster zones. Based on the foregoing, the study area was characterized into five different groundwater potential zones which are very low, low, moderate, high and very high groundwater potential zones.
Keywords: Basement Complex, Geomorphology, Lineament, Lineament Density, Groundwater Potential, Ekiti State.

1. Introduction

The population of Ekiti- State has been on the increase (1,416,293 in 1963; 1,628,762 in 1991; 1,750,000 upon its creation in 1996 and 2,384,212 from 2006 population census). As a result of this, there has also been corresponding increase in demand for potable water by the inhabitants for both domestic and industrial usages. However, public water supply has been grossly inadequate in spite of efforts of government and its parastatals. The shortfall in water demand has been partly met via groundwater development through hand dug wells, springs and the available boreholes. According to Ekiti State Rural Water Supply and Sanitation Agency, the failure rate in the previously drilled boreholes in the State is around 54% probably due to lack of detailed hydrogeological and pre-drilling geophysical investigation or poor understanding of the hydrogeological characteristics of the basement complex environment. The poor understanding of the hydrogeological characteristics may be due to poorly executed feasibility study or lack of it. (Ademilua 1997) attempted to classify the basement complex areas of the defunct Ondo State which now comprises of both Ondo and Ekiti States into different groundwater potential zones but was constrained by few VES data points and few numbers of sampled localities. Hence, the groundwater potential map produced by the researcher may not be representative. Therefore an assessment of the potentials of Ekiti State using enhanced data and parameters which is preceded by reconnaissance investigation becomes imperative. This paper intends to carry out a preliminary assessment of the groundwater potentials of Ekiti State using geomorphological and geological/ hydrogeological and lineament data.

(Edet et al., 1994) used the lineament analysis for groundwater exploration in the Precambrian Oban Massif and Obudu Plateau in the southeastern part of Nigeria. Their findings include amongst others that lineament density may provide some guide to groundwater potential areas in crystalline terrains. Such potentials can be targeted by identifying fractured zones of higher permeability (Greenbaum 1985). With the aid of this technique, a regional potential map can be produced (Masoud & Koike 2006). Landsat ETM+ imageries and Digital Elevation Model, obtained from the Shuttle Radar Topographic Mission (SRTM-DEM) were used to analyze the spatial variation in the orientation of the lineaments, and correlated them with the geology and hydrogeology of the SIWA region, NW, Egypt. (Sander 2006) gave a general overview of lineament mapping and interpretation for groundwater exploration in semi-arid hard rock areas. The author observed that hydro-tectonic models and impact of original or present stress regimes were exaggerated when analyzing lineaments; hence, large compressional stress perpendicular to the mapped features will to some extent negatively affect its transmissive properties, while compressional stress parallel to the inferred fracture zone will tend to open the feature.

2.1 Description of the Location and Geology of the Study Area.

Ekiti State lies within Latitudes $7^{0}15^{1}00^{11}$ and $8^{0}10^{1}00^{11}$ North of the Equator and Longitudes $4^{0}45^{1}00^{11}$ and $5^{0}50^{1}00^{11}$ East of the Greenwich Meridian. It is underlain by the Precambrian rocks of the Basement Complex of Southwestern Nigeria which cover about 50% of the land surface of Nigeria (Figure 1). The Basement Complex forms part of the mobile-belt east of the West African Craton and it is polycyclic. The rocks are concealed in places by a variably thick overburden. The major lithologic units according to (Rahaman 1976) and (Rahaman 1988) are the migmatite-gneiss complex; the older granites; the charnockitic rocks; the slightly migmatised to unmigmatised paraschists and metaigneous rocks and the unmetamorphosed granitic rocks. The migmatite-gneiss complex is composed mainly of early gneiss, mafic and ultramafic bands and the granitic or felsic components. The rock type is the most widespread, covering about half of the study area (Figure 2). The older granites comprise the porphyritic-biotite granite and the medium-coarse grained granite gneiss. The charnockitic rocks are composed of quartz, alkali feldspars, plagioclase, orthopyroxene, clinopyroxene, hornblende, biotite and accessory minerals such as apatite, zircon and allanite. The slightly migmatised to unmigmatised paraschists and metaigneous rocks consist of pelitic schists, quartzites, amphibolites, talcose rocks, metaconglomerates, marbles and calc-silicate rocks. The umetamorphosed granitic rocks manifest as dolerite dykes, pegmatites and quartz veins.

2.2 Hydrogeology

The major surface waters in the study area are rivers Ogbese, Osun, Oni, Osse and Ero and their tributaries. The volume of water in the streams depends on the response to wet and dry seasons. During the rainy season, there is a great increase in water flow volume in the major rivers while there is hardly water in some of the streams during the dry season. Rainfall is the dominant factor that determines the occurrences of groundwater. As such, this factor greatly influences the groundwater in the study area. During the rainy season, the area enjoys a high amount of rainfall. Rainfall data for the last 40 years show that the highest rainfall occurs in August while the lowest is recorded in November (Ademilua 1997).

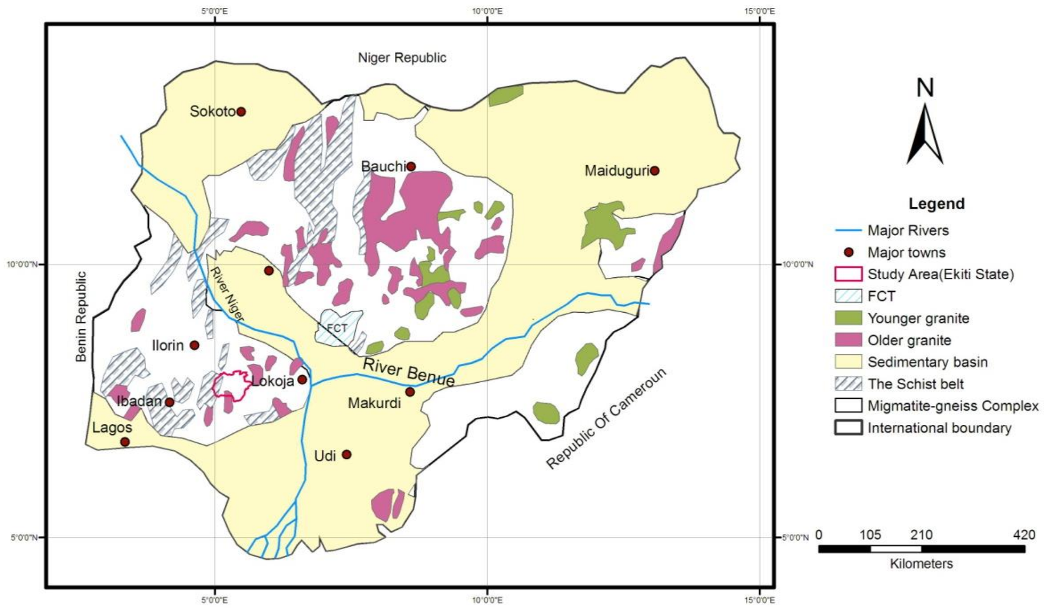

Figure 1: Geological Map of Nigeria (Digitized from (Ajibade & Umeji 1989))

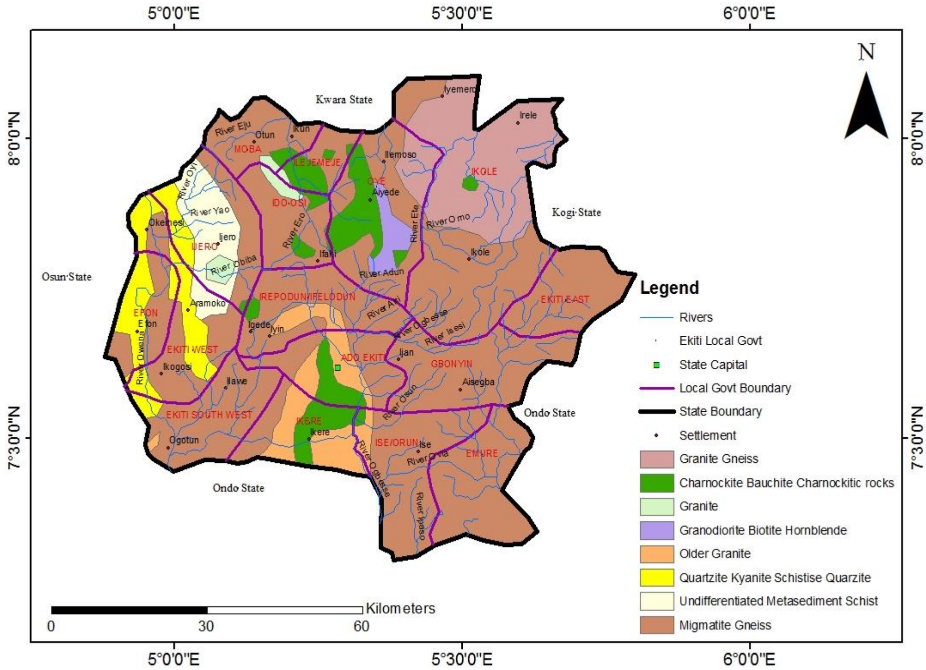

Figure 2: Geologic Map of Ekiti-State (Digitized from (Ademilua 1997))

In a typical Basement Complex area, groundwater occurs in the weathered mantle or in the joints and fractured basement column and buried stream channels (Vandenberghe 1982) and (Ako & Olorunfemi 1989). The rocks are mechanically competent (granites more so than gneisses) and therefore respond to imposed strains by brittle fracture. Surface water percolates down through the fractures and the process of chemical weathering proceeds.

3.0 Methodology

Digitized map of Ekiti State on a 1:100 000 scale topographic quadrangles was used to extract the lineaments through several false colour composites of bands 3, 4 and 5 of a Landsat TM dataset. Landsat TM data acquired during the dry season between the month of November and January (1986) were utilized for lineament extraction. Pre-processing data reduction (e.g haze reduction) was carried out on Landsat Thematic Mapper (TM) image dataset. This enhanced the signal to atmospheric noise ratio of the image. Image processing algorithms which include Normalized Difference Vegetative Index (NDVI), Principal Component Analysis (PCA), Directional Filtering, Colour Composite; and Linear Stretching were employed to enhance the image spatially and spectrally for lineaments extraction. Each processing operation was overlay on Digital Elevation Model (DEM) in order to authenticate the origin of the lineaments. ArcGIS 9.3 and ERDAS Imaging processing software were used to perform all the operations. The extracted lineaments were classified by drawing rose diagram which discerned the orientation and frequency of occurrence of the extracted lineaments. The extracted lineaments were converted to vector formats in ArcGIS 9.3 environment. The information from the satellite imageries of the study area were presented in form of lineament, lineament intersection, lineament density, lineament intersection density maps and rose diagram showing the distribution of lineaments based on azimuthal direction and frequency of lineaments.

4.0 Results and Discussion

4.1 Deductions from the Hydrogeomorphological and Geologic/Hydrogeologic Maps

The Hydrogeomorphological Map

The hydrogeomorphological map of the study area is shown in Figure 3. The landforms identified in the area include hills, ridges, pediments, pediplains, pediplain with alluvium and valley fills. Hills in the area are divided into denudational hills, residual hills and structural hills which are mainly made up of quartzites, gneisses, granites and charnockites and are mostly covered with the forest leaving no common tonal characteristic for their identification except the quartzite ridges that cut across Okemesi through Ikogosi and Efon. However, the rocks could be identified from their massive size and domal to elliptical shapes. The rugged topography in this region could be due to erosion of hills to an undulating plain leaving the rocks exposed. The pediments are the gently sloping undulating surfaces with or without a veneer of weathered/soil materials usually formed at the foot of a mountain and often dotted with rock outcrops. It occurs as narrow strip adjoining to hills at relatively elevated zones. Most pediplains occur normally along fractures which controlled the valley course (Lokesha et al., 2005).

The pediplain with alluvium is characterized by riverine deposits and could serve as good water containment. The valley fills are developed due to deposition of transported and or weathered materials in valley areas and are normally controlled by lineaments. They are low linear areas occurring between hills. The valley fill deposits are colluvio-fluvial in origin and are derived from weathering and deposited by the action of streams at floor of valleys. The valley fills are lowland between the structural hills around Efon-Alaaye in the western part of the study area. According to (McFarlane et al., 1992) and (Henriksen 1995), the topography and landforms have strong influence on groundwater prospect of an area as they influence the thickness of weathered zone. Plains or valleys will normally yield significant quantity of groundwater than steep slopes or sharp ridges. Therefore, to a certain extent the groundwater prospect can be predicted using topographic considerations. Hence, in this study, areas within the valley fills (230 - 333 m a.s.l), the pediplain with alluvium (333 – 435 m a.s.l), pediplains (435 – 538 m a.s.l), pediment (538 – 640 m a.s.l) and hills and ridges (640 – 743 m a.s.l) could be classified as having tendency for very high, high, moderate, low and very low groundwater prospect respectively (Table 1).

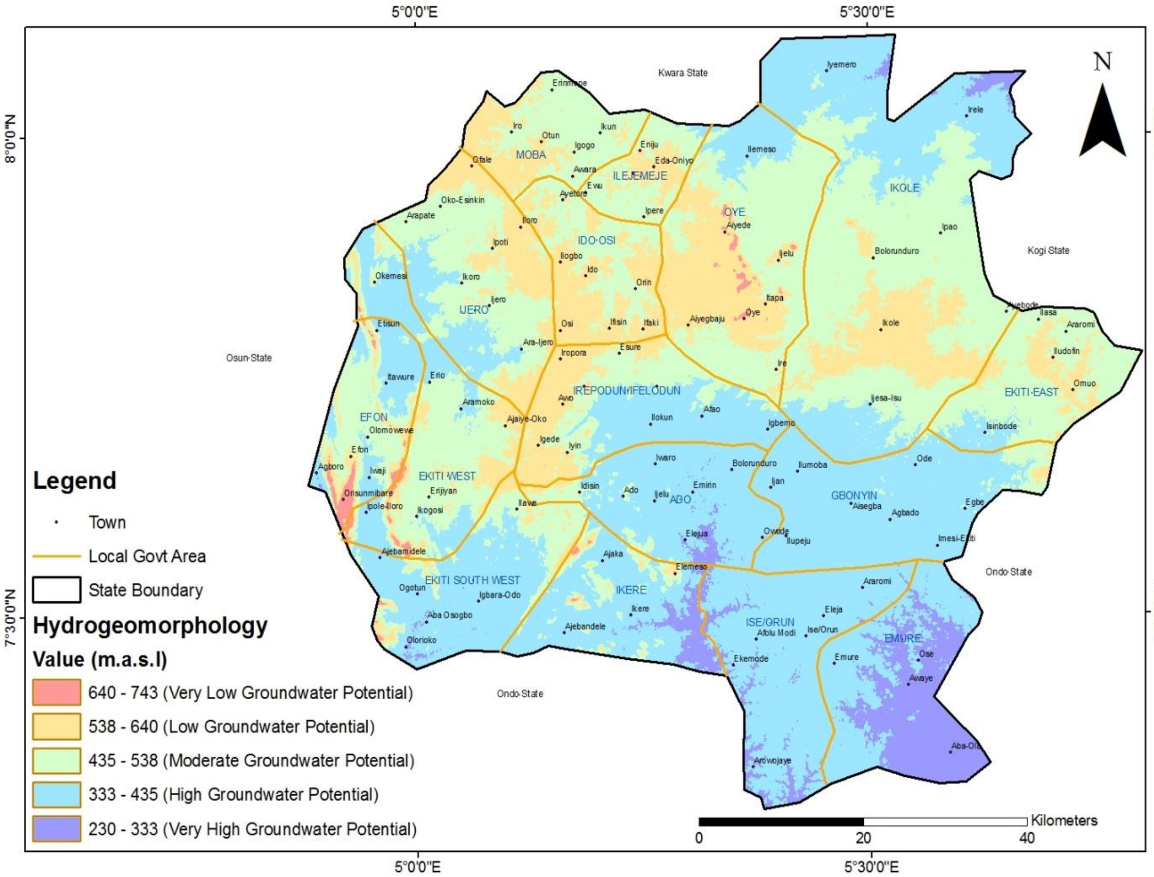

Figure 3: Hydrogeomorphological Map of Study Area (Source: Fieldwork/Satellite Imagery of the Study Area).

Table 1: Groundwater Prospect of the Study Area Based on Hydrogeomorphic Units.

Hydrogeomorphic Units / Colour Code	Height Above Sea Level (m)	Groundwater Prospect
Valley Fills (Purple)	230 – 333	Very High
Pediplain with Alluvium (Blue)	333 – 435	High
Pediplains (Green)	435 – 538	Moderate
Pediment (Yellow)	538 – 640	Low
Hills and Ridges (Red)	640 – 743	Very Low

4.2 The Geological Lineaments Map

Lineaments provide the pathways for groundwater movement and are hydrogeologically very important (Sander et al., 1996)). In hard rock terrain, the movement and occurrence of groundwater depend mainly on the secondary porosity and permeability resulting from folding, faulting and fracturing etc. These structural features appear on remote sensing imagery as lineaments. The remote sensing data offer synoptic view of large area and helps in understanding and mapping of the lineaments both on regional and local scale. By visually interpreting the satellite imagery, the lineaments of the study area were identified and traced on the basis of tonal, textural, soil tonal, vegetation, topographic and drainage linearity, curvilinear ties and rectilinear ties (e.g (Lillesand 1989), (Drury 1990) and (Gupta 1991). Figure 4 shows the generalized lineaments map of the study area. The map shows that there are four predominant sets of lineaments. One set of the lineaments trends N-S direction, the second set trends ENE-WSW direction, the third E-W and the fourth set trends NW-SE direction. The rose diagram of identified lineaments, showing the four major lineaments developments in the study area is shown in Figure 5. Figure 4 shows that the western part is characterized by very high lineament density and the central part with high lineament density. The northwestern, southwestern and southern parts of the study area are characterized by moderate lineament density while the east and northeastern parts have low to very low lineament density.

4.3 Hydrogeologically Significant Lineament Map

Figure 6 shows the hydrogeologically significant lineament map. The map was prepared by removing all lineaments that fall on hills, ridges and those on streams and river channels which are presumed not to be structurally controlled in the study area.

4.4 The Lineament Intersections Map

Figure 7 presents the lineament intersections map of the study area. Lineament intersections are sites for appreciable groundwater accumulation in a hard rock terrain. Lineament intersections represent nodal point for two or more lineament lines. In this study, the lineament intersection map was generated from the hydrogeologically significant lineaments map using the ArcGIS 9.3 platform. It is obvious from the map that the lineament intersection nodes are concentrated within the North-Western, Western and South-Eastern parts of the study area while other areas are characterized by scanty or no lineament intersection nodes.

4.5 The Hydrogeologically Significant Lineament Density and Lineament Intersection Density Maps

Lineament density map is one of the important thematic maps prepared from the lineaments, which are critically used in groundwater studies related to hard rock terrain ((Subba 1992)), (Krishnamurthy et al., 1996)). Figures 8 and 9, respectively present the hydrogeologically significant lineament density map and the lineament intersection density map of the study area. Lineament density map is a measure of cluster of linear features in a particular area. The peaks in the lineament and lineament intersection density contour maps are the places of interest for groundwater resource development. Areas with high lineament density excluding (the residual hill environment) are good for groundwater development (Haridas et al., 1994). In the present study, the hydrogeologically significant lineament intersection density maps show five different hydrogeological potential zones distributed as patches in the study area (Figures 8 and 9). The zones are summarized in Tables 2 and 3, respectively. Considering the groundwater potential classifications in Tables 2 and 3, it is clear from the lineament and lineament intersections density maps that areas such as Efon, Okemesi, Itawure, Ipole-Iloro, Aramoko, Ilumoba, and Ikogosi that constitute the western and the central parts of the study area show tendency for very high groundwater potential. Areas within the localities are characterized by very high lineaments and lineament intersections density. Areas around Ilemeso, Iludofin, Soso-Arapate and Igbara-Odo show high groundwater potential tendency. The areas show very high lineaments density but high to medium lineament intersection density. Areas around Otun, Ipere, Iwaji, Ijan and Ijesa-Isu show tendency for high groundwater potential. These localities fall within high lineament density and medium lineament intersections zones. Areas around Ikere, Ilawe, Ogotun, Ipao, Ifaki, Ode and Ayetoro fall on moderate groundwater zones. These towns are characterized by medium to low lineament density and lineament intersection density. On the other hand, Ido, area around Ipoti, Ose, Irele, Igogo, Ofale and Erio areas have tendency for low groundwater potential. The towns fall within low lineament density and lineament intersections zones. Moreover, localities around Ewu, Ise/Orun, Emure, Ikole, Oye, Aiyede, Igede, Iyin, Eyio, Ado-Ekiti, Osi, Ijero and Iyemero fall within very low groundwater potential zone. These localities are characterized by very low lineament density and lineament intersection density.

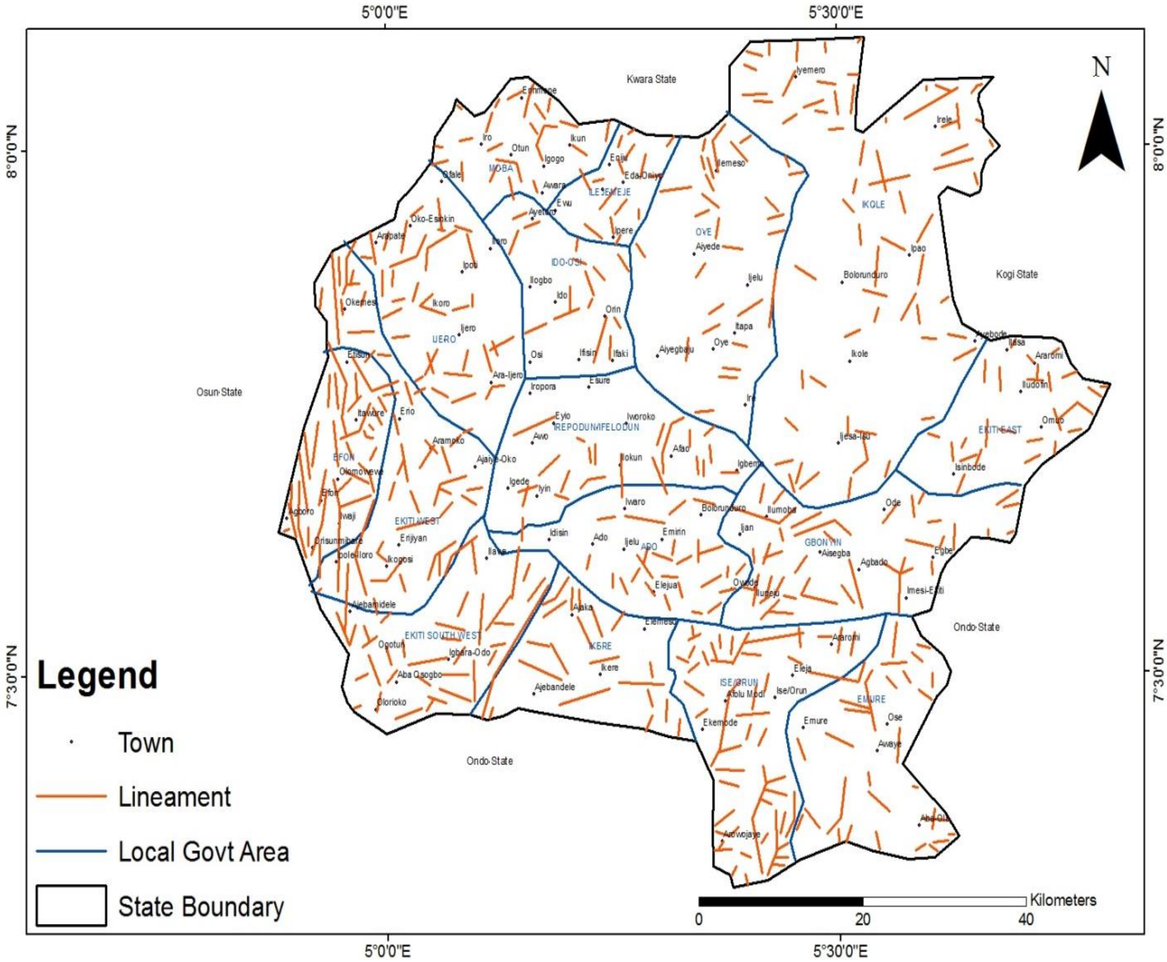

Figure 4: Generalized Lineament Map of the Study Area (Extracted from Landsat Imagery of Ekiti State).

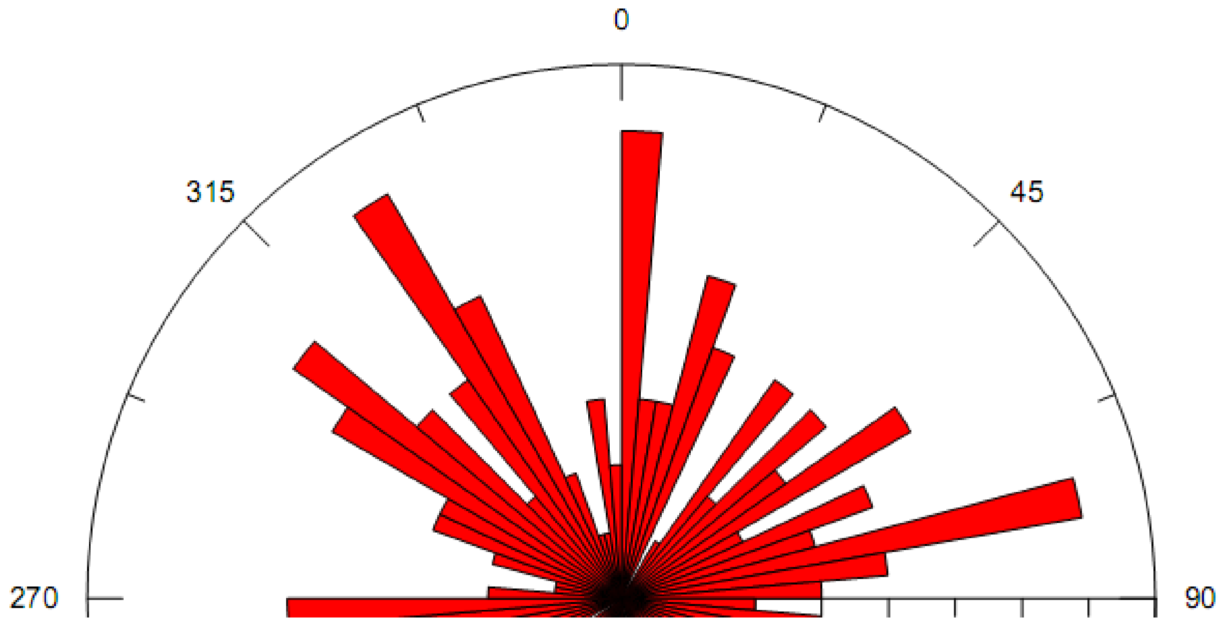

Figure 5: Rose Diagram showing the Generalized Lineament Trend.

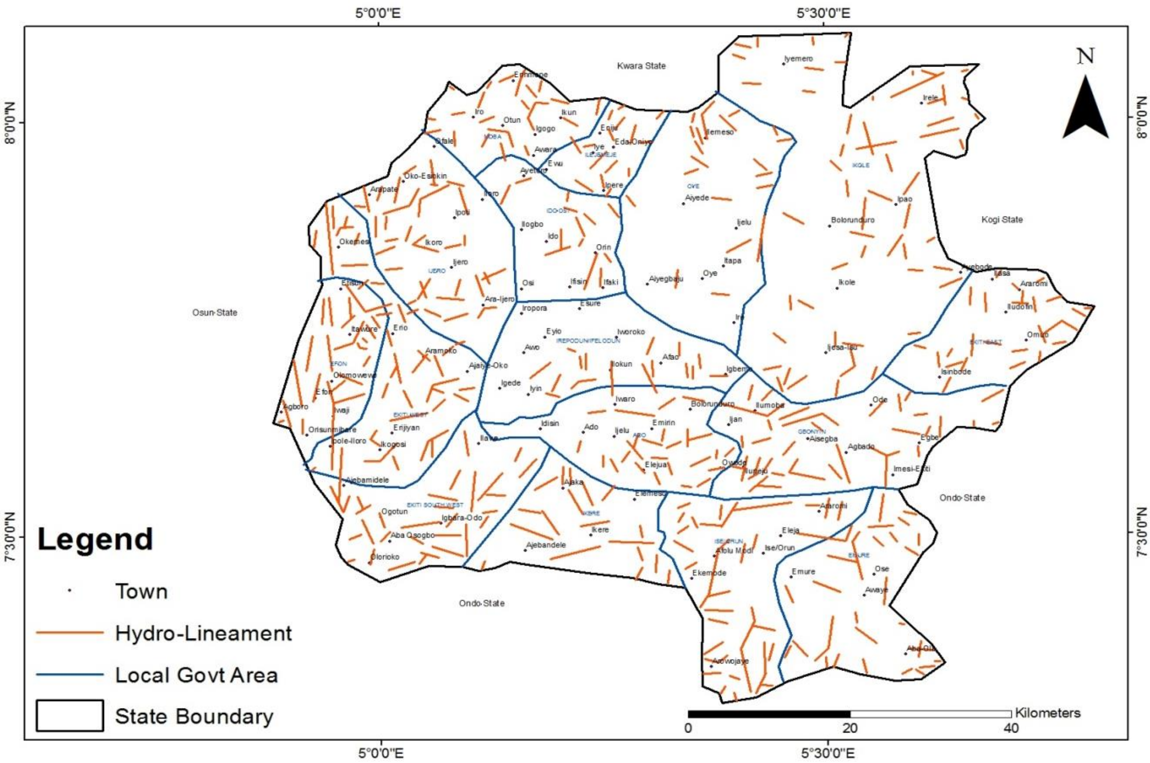

Figure 6: Hydrogeologically Significant Lineament Map of the Study Area (Extracted from Landsat Imagery of Ekiti State).

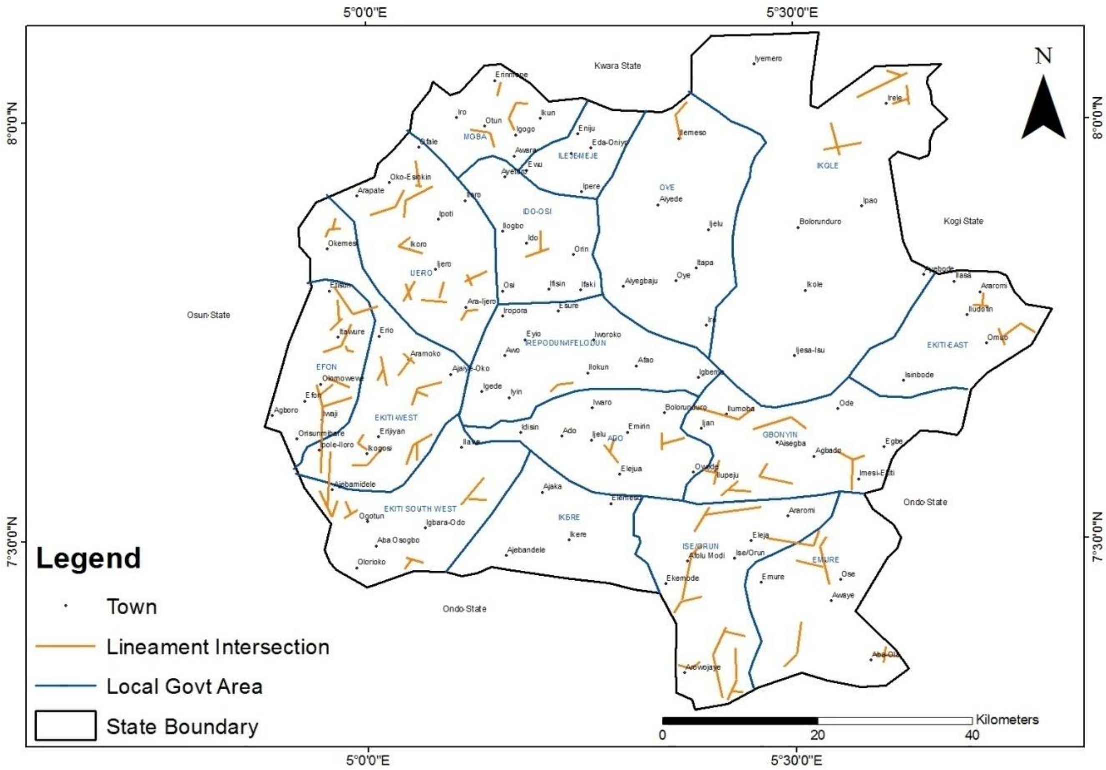

Figure 7: Lineament Intersection Map of the Study Area (Extracted from Landsat Imagery of Ekiti State).

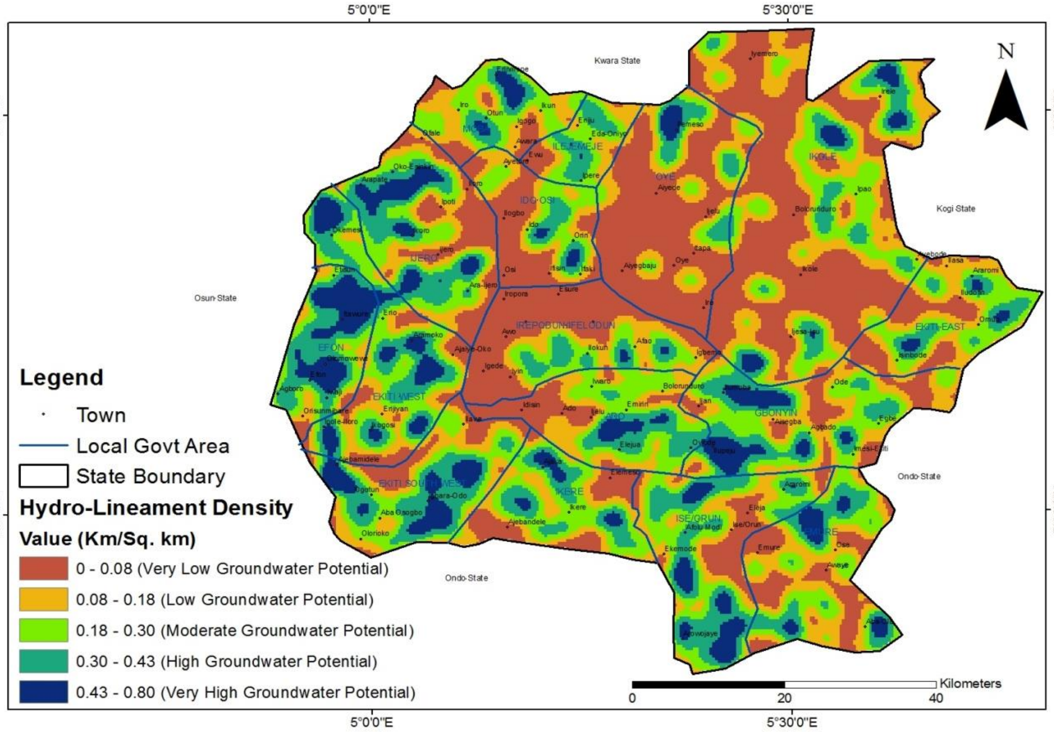

Figure 8: Hydrogeologically Significant Lineament Density Map of the Study Area.

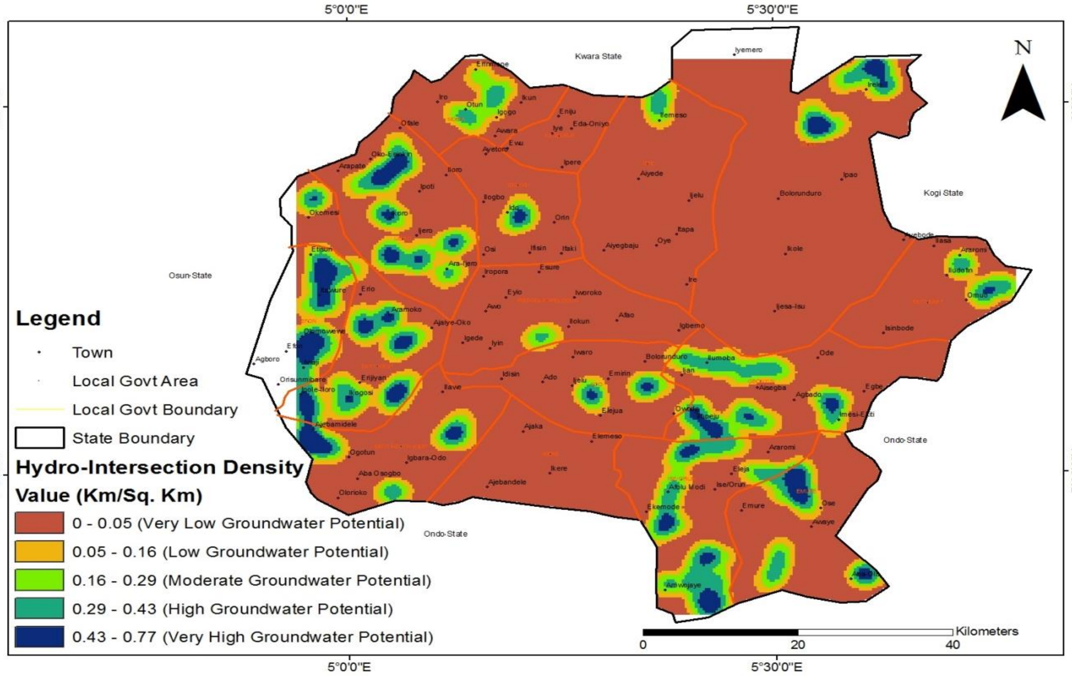

Figure 9: The Lineament Intersection Density Map of the Study Area.

Table 2: Groundwater Prospect of the Study Area based on Lineament Density.

Lineaments Density Colour Code	Lineaments Density Range (Km/Sq Km)	Groundwater Prospect
Deep Blue	0.43 – 0.80	Very High
Light Blue	0.30 – 0.43	High
Green	0.18 – 0.30	Moderate
Orange	0.08 – 0.18	Low
Brown	0 – 0.08	Very Low

Table 3: Groundwater Prospect of Study Area based on Lineament Intersection Density

Lineament Intersections Density Colour Code	Lineament Intersections Density Range (Km/Sq Km)	Groundwater Prospect
Deep Blue	0.43 – 0.77	Very High
Light Blue	0.29 – 0.43	High
Green	0.16 – 0.29	Moderate
Orange	0.05 – 0.16	Low
Brown	0 – 0.05	Very Low

5.0 CONCLUSIONS

The Digital Elevation Model (DEM) of the study area showed that the area comprised of valley fills (230 - 391 m a.s.l), the pediplain with alluvium (391 – 430 m a.s.l), pediplains (430 – 491 m a.s.l), pediment (491 – 545 m a.s.l) and hills and ridges (545 – 743 m a.s.l). Llineaments extracted from Landsat Thematic Mapper (TM) satellite imagery (1986) of Ekiti State showed four predominant sets of N-S, ENE-WSW, E-W and NW-SE. Hydrogeological significant lineament and lineament intersection maps were produced from the generalized lineament map of the area. The maps were used to produce the hydro-significant lineament and lineament intersection density maps of the area. The hydro-significant lineament density map revealed five (5) lineament cluster zones in the range of 0-0.08, 0.08-0.18, 0.18-0.30, 0.30-0.43 and 0.43-0.80 Km/SqKm. The lineament intersection density map also identified cluster zones in the range of 0-0.05, 0.05-0.16, 0.16-0.29, 0.29-0.43 and 0.43-0.77 Km/SqKm. The map showed that lineament intersection nodes are concentrated in the north-western, western and south-eastern parts of the study area while other areas are characterized by scanty or no lineament intersections nodes. Efon, Okemesi, Itawure, Ipole-Iloro, Aramoko, Ilumoba, and Ikogosi fall within the very high lineaments and lineament intersections density zones. However, localities like Ilemeso, Iludofin, Soso-Arapate and Igbara-Odo showed very high lineament density but high to medium lineament intersection density. Areas such as Otun, Ipere, Iwaji, Ijan and Ijesa-Isu showed high lineament density and medium lineament intersection zones. Ikere, Ilawe, Ogotun, Ipao, Ifaki, Ode and Ayetoro fall within medium to low lineament density and lineament intersection density. On the other hand, Ido, Ipoti, Ose, Irele, Igogo, Ofale and Erio areas have low lineament density and lineament intersection density values. Ewu, Ise/Orun, Emure, Ikole, Oye, Aiyede, Igede, Iyin, Eyio, Ado-Ekiti, Osi, Ijero, and Iyemero fall within the very low lineament density and lineament intersections density zones. The study area can therefore generally be classified into very low, low, moderate, high and very high groundwater potential zones

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